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## A STUDY OF EXCESSIVE RAINFALL

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[Weather Bureau, Washington, D. C., April 1941]

The Weather Bureau, for statistical purposes, classifies excessive rainfall into four groups: Two of these are for short-period storms and give the minimum rate of fall, in terms of minutes, for a group of southern States as distinguished from the remainder of the country. The other two classes are established at 1.00 inch in one hour and 2.50 inches in 24 hours. The subject of excessive rains for short periods of time has been covered adequately by Yarnell;<sup>1</sup> we here take up the rates for longer periods of time than considered by Yarnell, covering the two time intervals of 1 hour and 24 hours. In a general way, the data are intended to supplement and extend the Yarnell material.

The study is limited in a number of ways. The period of record chosen was 1908-37, inclusive, to give the maximum number of stations possible. This limitation was most evident over the Great Plains and the West where scarcity of observations caused considerable irregularities. In numerous instances the data for these regions had to be ignored. With two exceptions, data were excluded for all stations that did not have a continuous record throughout the period. This restriction limits the study to records from 155 stations for the 30-year period. The data, for first-order stations only, often leave wide gaps between stations, but an attempt has been made to show the comparability between these and cooperative stations.

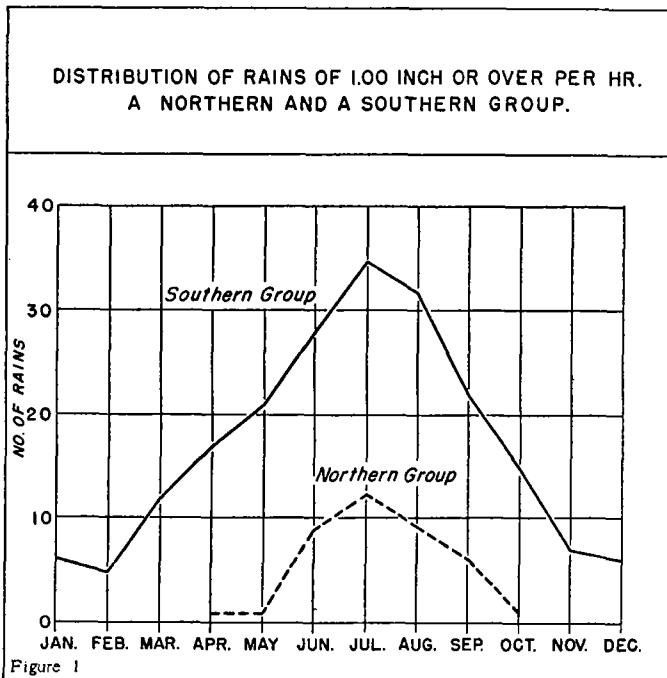
Many authorities cite as a serious deficiency in Weather Bureau records the fact that at most northern stations the tipping-buckets of the recording gages are removed during the winter months. The deficiency is not serious when precipitation of 2.50 inches or over in 24 hours is considered; undoubtedly the record of heavy rains in late fall or early spring is somewhat deficient, but the lack of these data may not be serious.

Figure 1 indicates a mean frequency distribution of rains of 1.00 inch or more per hour for a group of southerly stations and for a group of northerly stations chosen almost at random. The similarity between the two curves is apparent and if it may be said that the correspondence continues through the winter months, it is clear that the removal of the tipping bucket from the gage during the winter months has not resulted in any serious loss of record.

That an increase in average annual precipitation is attended by an increase in the number of rains of the 2.50/24 hour rate has been accepted in a general way and considered almost axiomatic. Figure 2 shows that this general conclusion is substantially correct, but the relation is somewhat more involved than generally believed. The spread of the dots in the figure illustrates vividly that the relation is general rather than specific and the curve of best fit is an approximation only. In fitting the curve several points were picked on one which had been sketched in free hand. These points were used in fitting the loga-

rithmic curve shown. The conditions prevailing on the north Pacific coast are so localized and peculiar to that region that they do not fit the general tendencies. Accordingly, data for those stations were omitted in this graph.

The applicability of precipitation data to areas of somewhat larger extent than the immediate vicinity of the gage itself has always been problematical. In this study, records for three first-order stations with nearby cooperative records available were examined, the latter covering the same period as the former. A comparison of rains of the 1.00 inch/hour rate was impossible, but a comparison



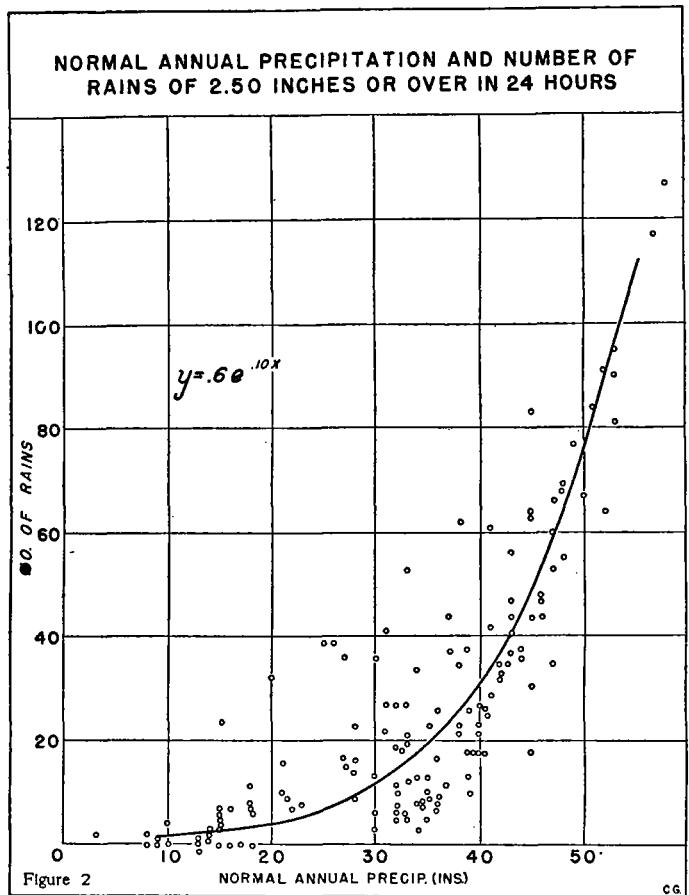
of those at the 2.50 inches/24 hour rate was made. The first-order stations and the nearby cooperative stations were as follows: Mobile-Citronelle, Ala.; Macon-Milledgeville, Ga.; and Nashville-Franklin, Tenn. In Alabama the cooperative station is about 20 miles northwest; in Georgia about 30 miles northeast; and in Tennessee about 18 miles south of the first-order stations, respectively.

The results of these comparisons are shown in figure 3. It may be seen that the same general tendencies are shown at both stations. As the cooperative observations are taken once a day and the rainfall amounts then recorded are for the preceding 24 hours, it may sometimes happen

<sup>1</sup> Yarnell, David L. *Rainfall intensity-frequency data*. U. S. Dept. of Agriculture Misc. Pub. 204. Washington, August, 1935.

that an observation will occur during a period of heavy rain, thus splitting the total amount for a storm. Accordingly, a supplemental tabulation was made of all rainfall amounts on two successive days that would add up to 2.50 inches or more. It is realized that this procedure can hardly be considered as refined, but the additional data were added to the original tabulation and the result tabulated as "adjusted" values. In each case the shape of the curve of the cooperative data was not materially altered, merely raising the whole series a few points.

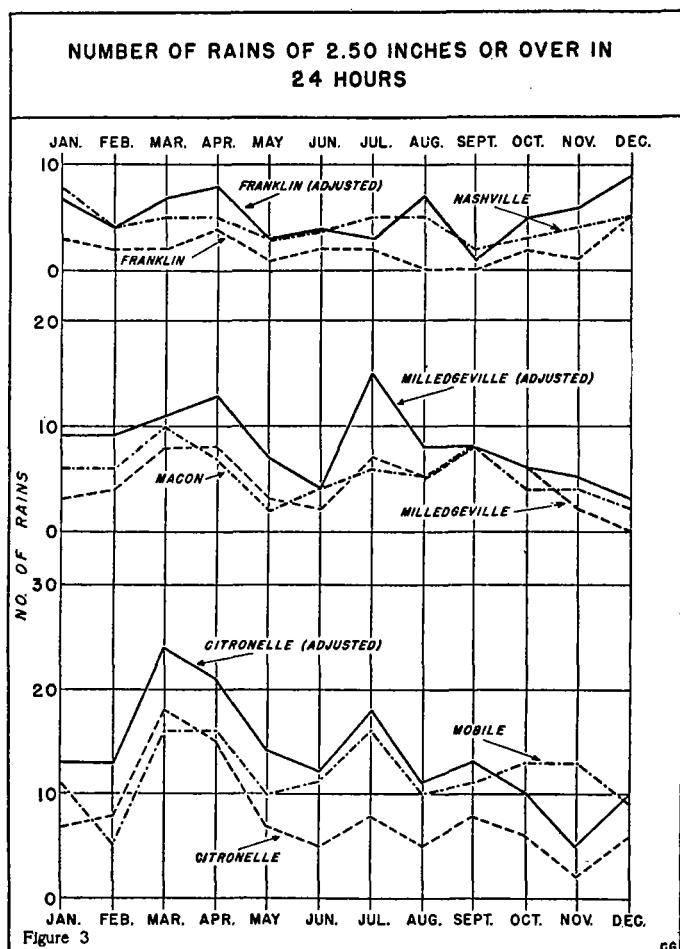
As the relation between precipitation and rains of 2.50 inches/24 hours appeared so acceptable, a comparison was made between rains of this rate and the average



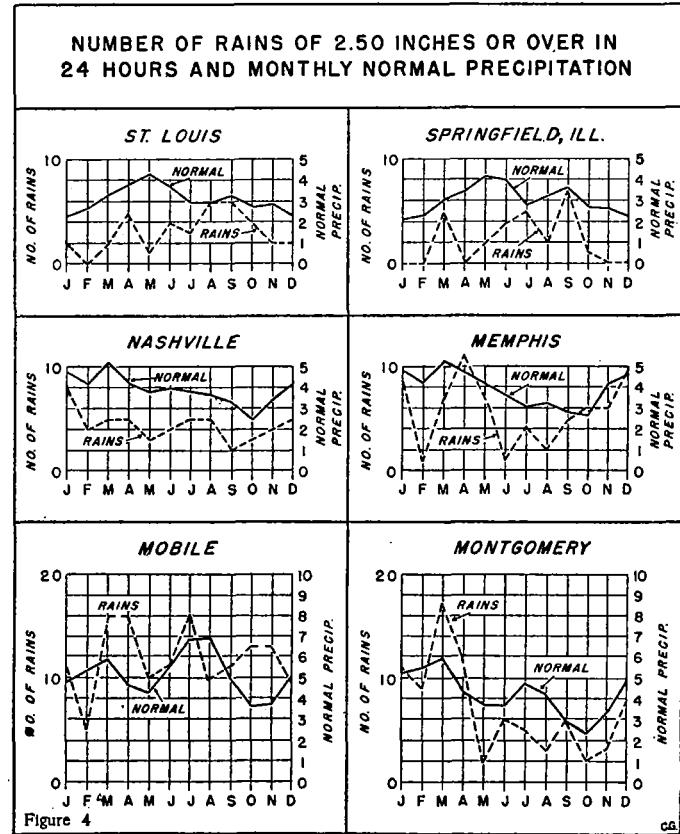
monthly precipitation. As shown in figure 4, there is no direct relation apparent between these values.

It was thought probable, however, that a group of stations chosen from a typical region might exhibit a better relation, and, consequently, six stations were chosen from each of three such regions. The results are shown in figure 5. For the stations in the South, the maximum points of frequency and average monthly rainfall coincide, while for the northeastern stations the maximum and minimum points of frequency display a lag of 1 month with respect to maxima and minima of the normal precipitation curve. There is apparently no direct relation in the Great Plains comparison. Marked, however, is the coincidence of the August frequency in the Great Plains and the northeast section.

The frequency of rains of different rates should exhibit the same general type of so-called "J" curve as other precipitation-frequency data. The rate of rainfall in inches per hour for each occurrence of rains of 1.00 inch or over in one hour was calculated for three widely-sepa-



— 1 —



**Figure 4**

rated stations. The results, shown in figure 6, are typical of usual precipitation frequencies. As the curves show the same general characteristics, it is believed that they are typical and representative of most stations.

The monthly distribution of rains at the rate of 1.00 inch/hour is illustrated in figure 7. Three southern stations in comparatively close proximity, Mobile, Pensacola, and Montgomery, were chosen, and three central

Rains of this rate may be expected once, or more, a year along the Middle Atlantic coast and generally south of the lower Ohio Valley and lower Missouri Valley. The immediate Gulf coast from east Texas to Florida and a narrow strip along the South Atlantic coast may expect at least two occurrences a year, while in southern Louisiana and Alabama and northwest Florida, from four to five occurrences are normal.

Figure 9 contains similar data for rains of 1.00 inch/hour. It shows that most of the country east of the Great Plains may expect, on the average, at least one such occurrence a year; that the central Gulf coast may expect at least 8 or 9, and that at least two such rains are likely to occur from eastern Kansas southward, as well as along the Atlantic coast northward to Washington, D. C. Notable in figures 8 and 9 is the effect of elevation in reducing the number of rains at excessive rates, as shown by the diminution over the Ozark and Appalachian regions.

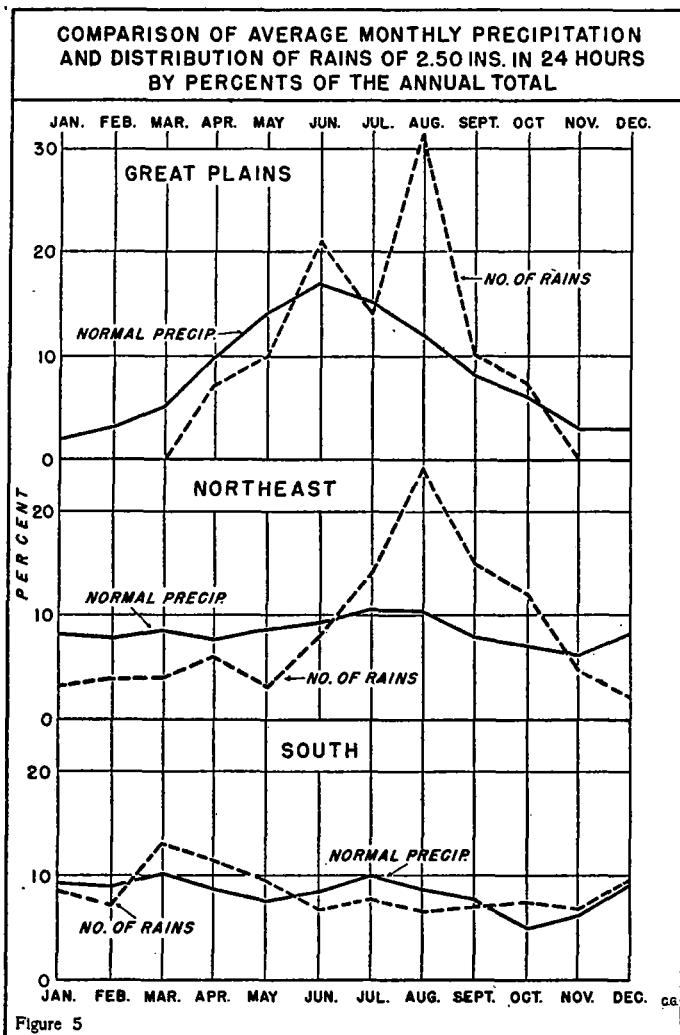


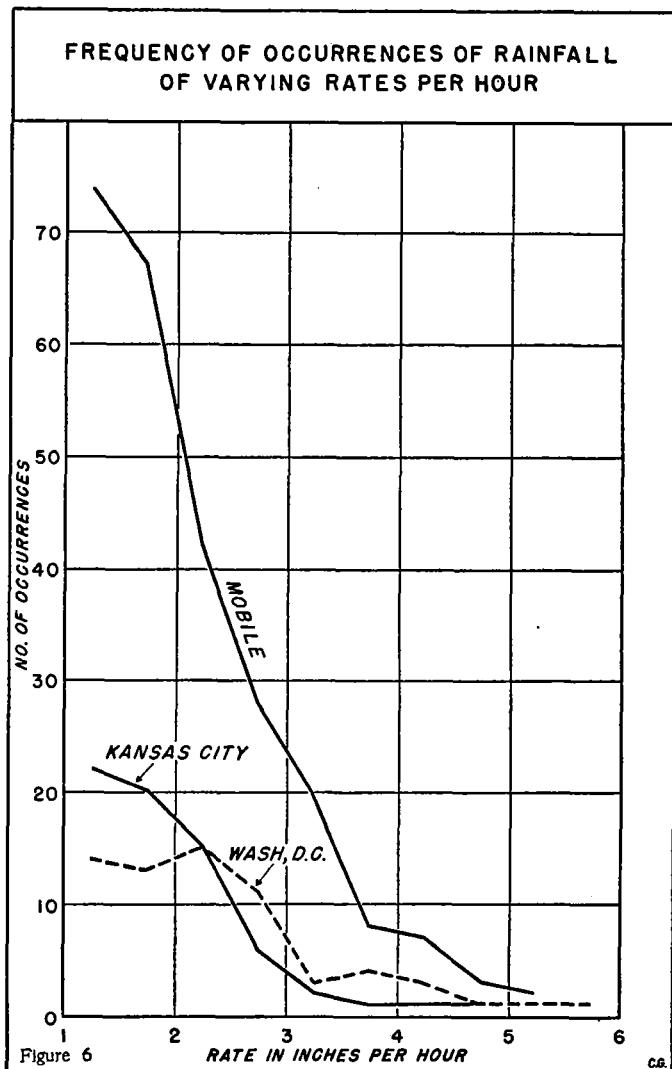
Figure 5

ones, Nashville, Memphis, and St. Louis. At the more northern stations the absence of occurrences in cold months prevents a good monthly comparison.

The southern stations exhibit much the same general characteristics. There is a winter minimum and summer maximum, but there is a secondary maximum in April in each case. Mobile shows a fall maximum in October, and Montgomery in November, but Pensacola declines steadily.

The distribution at the central stations is more erratic. St. Louis shows a maximum in August, Memphis in September, and Nashville a double maximum in June and August. The minimum at Nashville occurs in November, Memphis in January, and St. Louis from November to February.

The frequency of rains at various rates that may be expected, on the average, is an important consideration. Figure 8 shows the number of times that rains of 2.50 inches/24 hours occurred in the 30-year period, 1908-37.



The percentage of the annual precipitation that falls at the rate of 2.50 inches or more in 24 hours is an important matter and is shown in figure 10. From about one-fifth to one-fourth of the total annual amount falls at this rate along the Gulf coast, but there is a decline to only about one-twentieth in northern states.

Figure 11 shows the average rate in inches per hour of all rains at the rate of 2.50 inches or over in 24 hours. The great irregularities in the Northern Plains States are

due to relatively few occurrences and the consequent irregularities of the averages. The minimum rate per hour of this category of rains is about 0.104 inch per hour. This rate is approximated at Roseburg, Oreg., and ap-

With falls of 1.00 inch/hour, the hourly rate is greater, as shown on figure 12. Here the highest rates again appear in the Great Plains and central Rockies, with rather localized areas elsewhere.

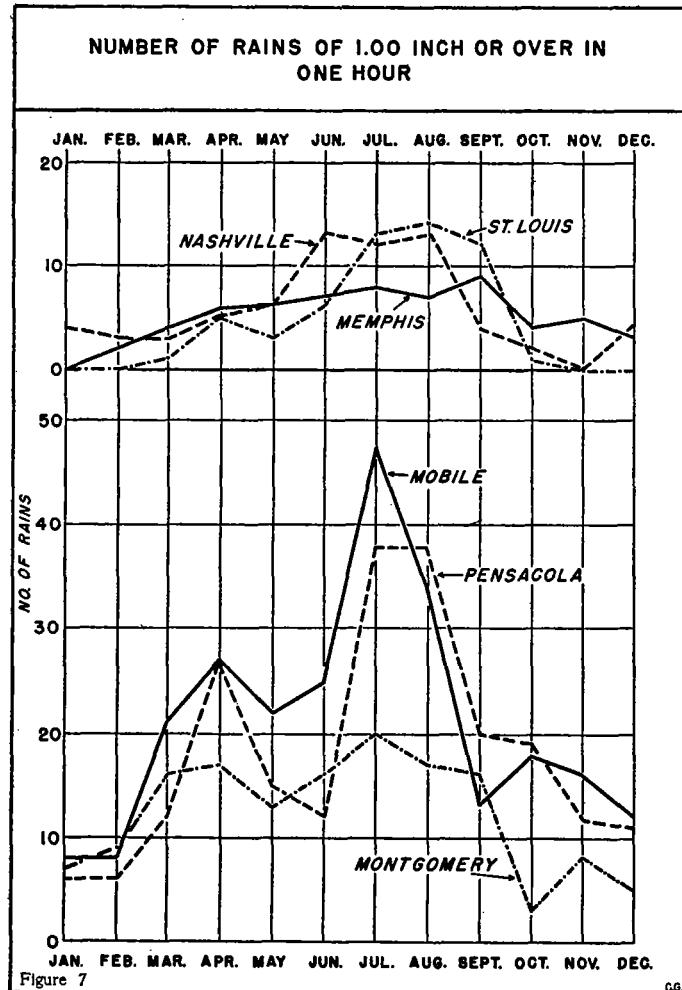
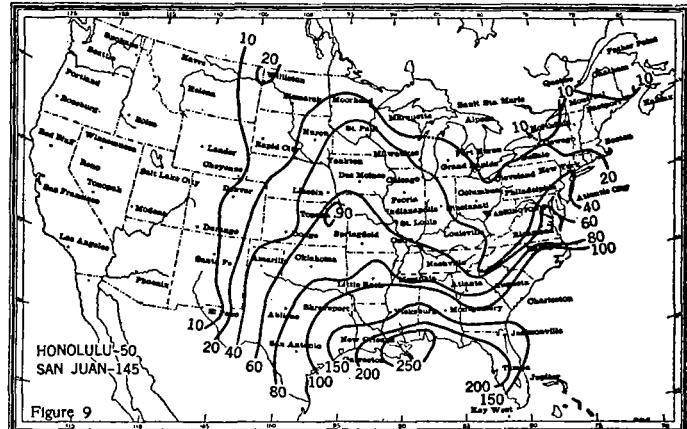
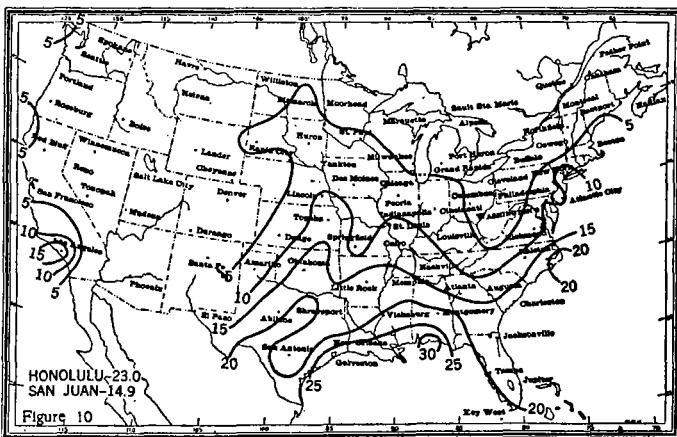


Figure 7



The greatest rate of fall in inches per hour, without regard to duration, is shown in figure 13. The widespread distribution of rates in excess of 4.00 inches per hour is noteworthy, practically all of the country east of the



Great Plains having had falls of this intensity, except small areas in the Northeast, the Lake region, and locally elsewhere. Rates exceed 5 inches per hour in the central Gulf area, most of Florida, and eastern North Carolina,

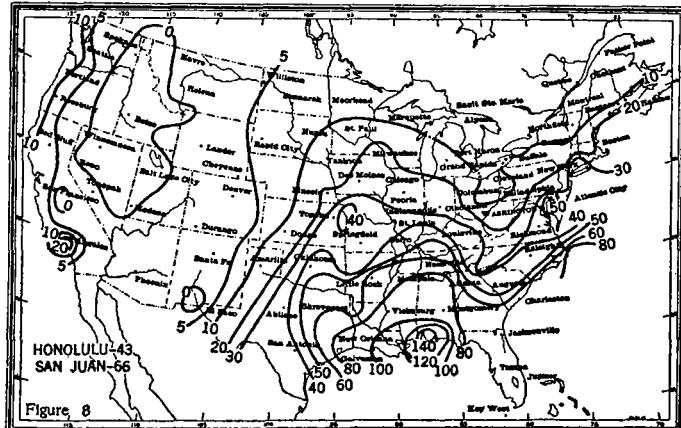
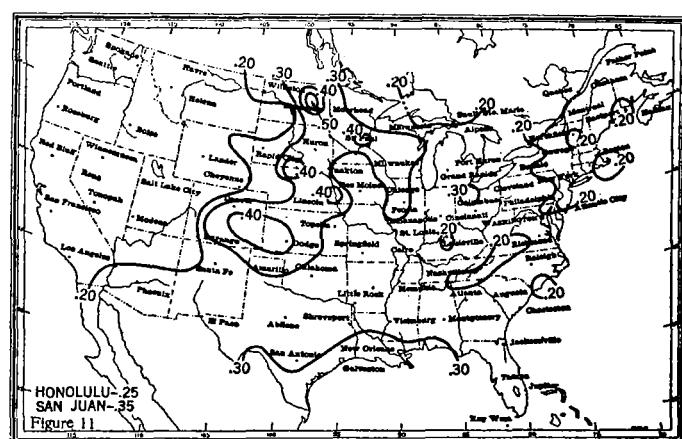


Figure 8



and local areas elsewhere, notably in the vicinity of Washington, D. C., Baltimore, Md., Minneapolis, Minn., and Devils Lake, N. Dak. The rate has exceeded 8 inches per hour at Montgomery, Ala., and Wilmington, N. C.;

This would seem to indicate that whenever such rains fall they are usually of quite long duration. The area of maximum intensity, exceeding the rate for heavy rain, is noted over the Great Plains, the upper Mississippi Valley, and along the Gulf coast.

while Minneapolis, Minn., shows 10.20 inches per hour, the highest of any of the group of stations used; at Minneapolis 1.02 inches fell in a period of only 6 minutes. The

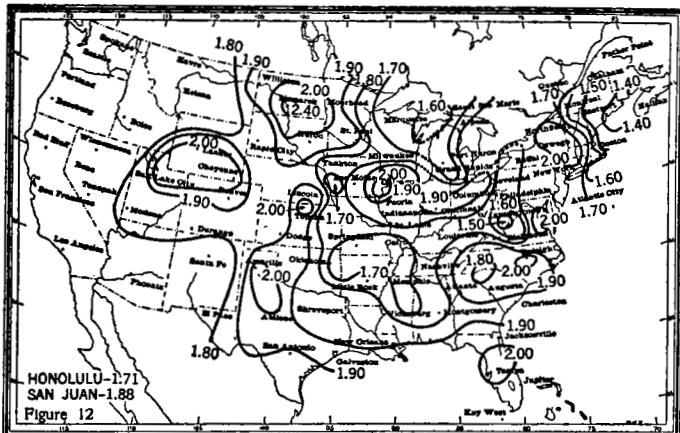
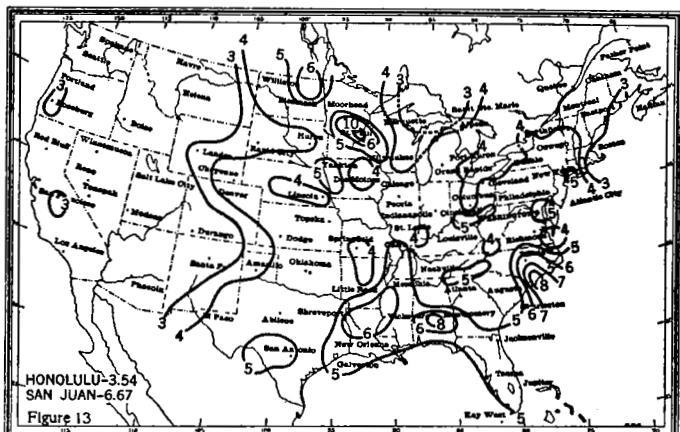


Figure 12

greatest number of maximum rates occur in August, but with an almost equal number in June and July.

Figure 14 shows the maximum amount of precipitation recorded at the rate of 2.50 inches or over in 24 hours. The central Gulf coast has exceeded 16 inches, while from



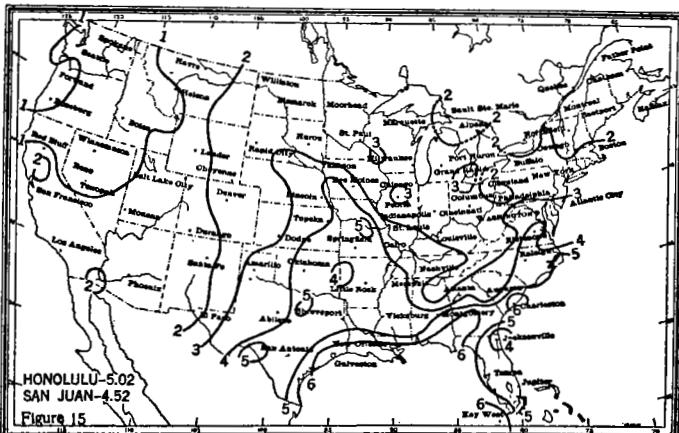
southern Maine southward along the Atlantic coast, the greatest fall has exceeded 6, 8, and 12 inches locally.

Figure 15 shows the maximum amount recorded at the rate of 1.00 inch or over in 1 hour. A large central area,



as well as the central and south Atlantic coast section, have had rains of over 4 inches at this rate; the greatest fall was 14.45 inches in 9 hours 35 minutes at Pensacola, Fla.

The duration of rain at the different rates is just as important as the depth of fall. Figure 16 shows the average duration of rains at the rate of 2.50 inches/24 hours.



In general, the charts probably show numerous significant features, taken separately or together, that have been overlooked or neglected in this discussion.

Tables are included containing data for all the stations studied: Table 1, tabulations of the number of occurrences of rains at the two rates as well as the average amount, duration, and per hour rate for each. Table 2, tabulations of the maximum amount of precipitation at each rate, with its duration, and the maximum rate in inches per hour. Table 3, the monthly and annual number of rains at the 2.50/24 hour rate, and table 4 similar data for the 1.00/hour rate.

Extensive interpretation of these results has not been attempted because it is felt that users of the data would necessarily interpret them in relation to their specific problems.

TABLE 1.—Total number of occurrences of rains of 2.50 inches in 24 hours or more and of rains of 1.00 inch per hour or more and average amount, duration, and rate per hour for each group

Station	Number		Averages					
	2.50 inches in 24 hours		1.00 inch in 1 hour				Duration	Rate/inch/hour
	Amount	Hours	Minutes	Amount	Hours	Minutes		
Abilene	39	77	3.67	13	17	0.28	1.37	0
Albany	10	13	2.95	17	22	.17	1.23	0
Alpena	3	14	3.22	14	24	.22	1.21	0
Amarillo	16	42	3.19	10	30	.30	1.34	0
Asheville	18	36	3.62	19	10	.19	1.25	0
Atlanta	55	76	3.48	16	36	.21	1.43	0
Atlantic City	30	39	3.91	19	44	.20	1.41	0
Augusta	44	97	3.44	13	33	.25	1.33	0
Baker	0	0	0	0	0	0	0	0
Baltimore	44	51	3.35	17	22	.19	1.29	0
Binghamton	13	25	3.23	17	10	.19	1.20	0
Birmingham	81	129	3.45	14	30	.24	1.30	0
Bismarck	7	14	3.15	17	31	.18	1.30	0
Block Island	26	23	3.43	17	39	.19	1.36	0
Boise	0	0	0	0	0	0	0	0
Boston	27	13	3.59	19	49	.18	1.57	1
Buffalo	8	10	2.77	12	31	.22	1.41	0
Burlington	6	14	3.41	21	22	.16	1.18	0
Cairo	42	61	3.54	14	38	.24	1.30	0
Canton	9	9	2.90	16	35	.17	1.37	0
Charles City	27	51	3.28	12	07	.27	1.25	0
Charleston	63	124	3.74	12	38	.30	1.44	0
Charlotte	47	78	3.37	15	59	.21	1.32	0
Chattanooga	64	72	3.35	17	28	.19	1.24	0
Cheyenne	4	8	2.94	18	51	.16	1.31	0
Chicago	21	49	3.02	10	44	.28	1.27	0
Cincinnati	26	37	3.11	13	22	.23	1.25	0
Cleveland	8	16	3.06	10	24	.29	1.27	0
Columbia, Mo.	35	75	3.18	11	09	.29	1.31	0
Columbia, S. C.	37	80	3.35	14	12	.24	1.37	0
Columbus	9	24	2.96	14	20	.21	1.26	0
Concordia	15	59	3.47	10	0	.35	1.36	0
Corpus Christi	39	96	4.46	12	38	.35	1.52	0
Davenport	19	52	3.25	13	07	.25	1.25	0
Del Rio	33	60	3.72	11	59	.31	1.56	0
Denver	2	11	2.88	7	51	.37	1.26	0
Des Moines	27	48	3.09	12	0	.26	1.28	0
Detroit	10	25	3.22	11	01	.29	1.34	0
Devils Lake	8	17	3.40	6	28	.53	1.40	0
Dodge City	10	35	3.06	7	15	.42	1.40	0
Dubuque	20	46	3.61	9	19	.39	1.37	0
Duluth	9	20	3.22	12	57	.25	1.28	0
Eastport	10	10	3.27	16	19	.20	1.09	0
Elkins	18	34	3.08	11	10	.28	1.29	0
El Paso	0	5	0	0	0	0	1.17	0
Erie	12	25	3.24	13	41	.24	1.24	0
Escanaba	6	15	3.41	11	34	.29	1.23	0
Eureka	18	0	3.29	22	34	.15	0	0
Evansville	47	56	3.35	14	50	.23	1.30	0
Fort Smith	38	59	3.39	15	41	.22	1.22	0
Fort Worth	53	94	3.68	13	06	.28	1.43	0
Fresno	0	2	0	0	0	0	1.04	0
Galveston	83	167	4.16	11	59	.35	1.57	0
Grand Junction	1	0	2.50	23	59	.10	0	0
Grand Rapids	13	27	2.81	9	43	.29	1.21	0
Green Bay	11	29	3.15	8	47	.36	1.15	0
Harrisburg	22	38	3.32	15	14	.22	1.33	0
Hartford	31	27	3.10	17	53	.17	1.25	0
Hatteras	90	119	3.81	15	02	.25	1.48	0
Hevre	3	2	2.61	21	21	.12	1.40	1
Helena	2	1	3.26	21	52	.15	1.00	0
Honolulu	43	50	4.08	16	14	.25	1.51	0
Huron	10	26	3.20	8	23	.38	1.31	0
Indianapolis	23	42	3.11	13	28	.23	1.37	0
Jacksonville	67	154	3.66	13	57	.26	1.36	0
Kalispell	0	1	0	0	0	1.00	2.22	0

TABLE 1.—Total number of occurrences of rains of 2.50 inches in 24 hours or more and of rains of 1.00 inch per hour or more and average amount, duration, and rate per hour for each group—Continued

Station	Number		Averages					
	2.50 inches in 24 hours		1.00 inch in 1 hour		Duration		Rate/inch/hour	
	Amount	Hours	Minutes	Amount	Hours	Minutes	Amount	Hours
Kansas City	44	68	3.51	12	14	.29	1.46	0
Keokuk	27	56	3.20	10	38	.30	1.34	43
Key West	62	144	4.17	11	51	.35	1.49	49
Knoxville	35	45	3.05	13	18	.23	1.31	41
La Crosse	22	47	3.07	8	04	.38	1.32	46
Lander	1	2	3.31	24	0	.14	0.98	20
Lincoln	23	60	3.54	11	52	.30	1.50	47
Little Rock	68	88	3.57	15	27	.23	1.35	46
Los Angeles	24	3	3.37	19	52	.17	1.12	42
Louisville	37	43	3.28	16	59	.19	1.24	43
Lynchburg*	29	34	3.28	17	44	.18	1.27	46
Macon	64	98	3.61	14	36	.25	1.34	43
Madison	15	41	3.17	9	33	.33	1.10	40
Marquette	7	13	3.17	18	53	.17	1.31	47
Memphis	69	61	3.58	16	07	.22	1.43	52
Meridian	95	157	3.74	12	57	.29	1.36	44
Milwaukee	13	30	3.24	11	59	.27	1.33	45
Minneapolis	14	41	3.43	8	18	.41	1.25	47
Mobile	141	251	3.85	13	04	.29	1.39	40
Modena	0	5	0	0	0	0	1.21	39
Montgomery	84	147	3.91	15	31	.25	1.30	45
Moorhead	8	28	3.24	10	01	.32	1.36	40
Nantucket	23	19	3.29	17	14	.19	1.26	49
Nashville	53	69	3.21	14	28	.22	1.26	42
New Haven	44	31	3.22	17	33	.18	1.30	44
New Orleans	117	266	4.04	13	02	.31	1.50	47
New York	41	40	3.32	16	33	.20	1.31	42
Norfolk	36	67	3.37	14	34	.23	1.29	46
Northfield	8	7	3.68	16	59	.22	1.25	28
North Head	14	20	2.99	23	36	.13	0	0
North Platte	8	26	3.10	13	32	.23	1.33	43
Oklahoma City	41	71	3.65	13	01	.28	1.58	50
Omaha	16	43	3.47	8	41	.40	1.36	49
Oswego	5	10	2.92	14	05	.21	1.15	31
Palestine	61	101	3.64	13	45	.26	1.38	44
Parkersburg	13	38	3.41	13	14	.26	1.22	42
Pensacola	127	216	4.30	13	40	.31	1.64	53
Peoria	23	64	3.27	10	40	.31	1.28	42
Philadelphia	27	46	3.30	18	23	.18	1.27	42
Phoenix	2	6	3.90	15	08	.26	1.30	53
Pittsburgh	7	32	3.09	14	17	.22	1.15	39
Pocatello	1	3	2.60	16	58	.15	1.00	41
Portland, Maine	32	11	3.18	20	07	.16	1.13	48
Portland, Oreg.	12	1	3.48	23	56	.15	1.12	33
Providence	18	22	3.37	16	55	.20	1.47	54
Pueblo	2	16	2.82	6	14	.45	1.26	40
Raleigh	48	104	3.29	12	21	.27	1.30	39
Rapid City	11	15	3.53	17	20	.20	1.36	44
Reno	0	0	0	0	0	0	0	0
Richmond	35	64	3.60	14	57	.23	1.60	42
Rochester	5	11	2.99	11	32	.26	1.37	45
Roseburg	6	1	3.57	26	13	.14	1.10	15
Roswell	7	20	3.55	13	32	.26	1.41	49
Sacramento	6	1	3.10	22	20	.14	2.33	13
St. Louis	37	55	3.34	14	09	.24	1.38	46
Salt Lake City	0	1	0	0	0	0	1.05	30
San Antonio	36	83	3.79	13	04	.29	1.52	49
San Diego	4	1	3.09	20	48	.32	1.44	50
Sandusky	12	28	3.56	11	18	.32	1.39	45
San Francisco	7	1	3.16	21	50	.14	1.03	55
San Jose	6	0	0	0	0	0	0	0
San Juan	66	145	4.10	11	51	.35	1.41	45
Santa Fe	1	4	2.83	10	50	.26	1.03	38
Sault Ste. Marie	5	8	3.44	19	26	.18	1.06	45
Savannah	60	140	3.74	11	39	.32	1.50	48
Scranton	18	37	3.25	15	59	.20	1.18	39
Seattle	3	0	3.58	25	31	.14	0	0
Sheridan	3	5	3.50	17	33	.20	1.38	50
Shreveport	56	108	3.92	14	02	.28	1.38	44
Sioux City	17	44	3.27	10	55	.30	1.34	46
Spokane	0	0	0	0	0	0	0	0
Springfield, Ill.	26	51	3.43</td					

TABLE 2.—Maximum amounts and corresponding durations at 2.50 inches in 24 hours or more and at 1.00 inch per hour or more and maximum rate in inches per hour with duration

Station	Maximum amounts						Maximum rate in inch/hour	
	2.50 inches in 24 hrs.			1.00 in 1 hr.				
	Amount	Hours	Minutes	Amount	Hours	Minutes		
Abilene	6.78	23	58	3.86	1	50	4.50	28
Albany	4.23	18	0	1.64	0	35	4.68	15
Alpena	4.40	15	59	1.63	0	35	5.00	12
Amarillo	4.38	16	1	3.44	2	30	3.32	26
Asheville	7.92	19	52	2.65	0	45	5.93	18
Atlanta	11.75	57	4	3.62	2	18	4.77	18
Atlantic City	13.26	45	38	5.04	1	44	4.04	15
Augusta	9.82	16	15	3.31	2	10	4.67	37
Baker								
Baltimore	7.62	19	36	3.57	2	0	5.00	12
Binghamton	4.55	23	54	2.09	0	44	4.84	16
Birmingham	11.39	38	57	2.94	1	50	4.90	24
Bismarck	3.76	16	1	2.98	0	45	4.84	15
Block Island	4.48	16	30	2.93	2	50	2.88	25
Boise								
Boston	7.65	33	34	2.30	1	52	2.71	33
Buffalo	3.10	3	15	2.33	1	37	2.61	37
Burlington	4.70	25	12	1.95	0	52	3.75	16
Cairo	5.69	17	35	3.59	1	37	5.04	15
Canton	3.50	21	36	2.28	0	49	3.47	18
Charles City	5.32	9	50	2.70	1	13	3.60	25
Charleston	11.67	21	58	6.67	2	2	4.82	30
Charlotte	5.58	11	47	3.65	2	20	4.39	34
Chattanooga	7.36	40	15	2.48	0	45	5.31	20
Cheyenne	3.24	7	48	2.42	0	40	4.27	18
Chicago	4.34	12	47	2.30	1	0	4.64	15
Cincinnati	4.77	15	25	2.54	0	27	5.64	27
Cleveland	4.13	6	31	1.84	0	50	4.13	18
Columbia, Mo.	6.61	8	54	5.16	3	24	4.37	14
Columbia, S. C.	6.03	25	2	3.92	2	5	4.42	22
Columbus	3.71	16	18	2.70	1	20	3.98	19
Concordia	4.75	10	15	3.28	0	40	4.92	40
Corpus Christi	9.38	32	42	5.91	4	19	4.12	40
Davenport	5.00	14	1	2.68	0	46	4.80	20
Del Rio	8.88	11	16	5.02	1	7	5.23	25
Denver	3.00	8	43	2.14	0	54	4.50	22
Des Moines	4.87	5	8	3.08	1	29	4.00	18
Detroit	4.75	18	15	3.68	1	29	3.53	17
Devils Lake	4.53	4	43	2.62	0	38	6.08	22
Dodge City	3.51	2	33	2.66	1	26	4.10	29
Dubuque	5.48	5	4	2.64	0	45	4.03	18
Duluth	6.65	19	58	2.42	1	5	4.38	19
Eastport	4.09	20	30	1.36	0	45	2.97	22
Elkins	5.45	4	56	3.07	1	40	4.12	15
El Paso								
Erie	5.77	11	26	2.35	0	53	3.48	25
Escanaba	5.05	5	45	2.07	0	55	2.26	55
Eureka	5.15	27	43					
Evansville	10.77	41	43	3.01	1	48	3.82	25
Fort Smith	6.40	19	2	2.29	0	32	4.30	32
Fort Worth	9.57	17	12	5.72	2	11	4.06	25
Fresno								
Gaithersburg	13.54	31	45	6.47	1	34	5.49	20
Grand Junction	2.50	23	59					
Grand Rapids	3.36	12	30	2.10	0	43	4.28	15
Green Bay	4.41	22	28	2.10	0	45	3.80	18
Harrisburg	5.28	20	2	2.42	1	17	4.88	15
Hartford	5.19	23	54	2.79	0	42	4.31	16
Hatteras	12.54	26	53	5.33	0	58	5.51	58
Hayes	2.70	23	56	1.60	1	0	1.60	60
Helena	3.67	23	65	1.00	0	50	1.20	50
Honolulu	13.52	20	5	5.02	3	5	3.53	18
Huron	4.46	28	20	2.02	1	3	3.97	21
Indianapolis	4.45	13	42	2.59	0	52	4.12	15
Jacksonville	7.66	24	0	3.79	2	3	5.62	11
Kalispell								
Kansas City	7.03	9	52	4.50	1	50	4.53	16
Keokuk	5.88	15	1	2.89	1	24	4.37	14
Key West	14.00	26	14	6.49	5	31	4.76	15
Knoxville	6.20	12	8	3.19	1	51	4.20	20
La Crosse	3.96	10	32	3.14	1	25	5.12	13
Lander	3.31	24	0	1.22	0	21	3.49	21
Lincoln	8.38	8	35	3.85	2	44	3.75	49
Little Rock	9.58	19	0	4.23	2	47	4.00	15
Los Angeles	6.81	35	0	1.16	0	32	2.18	32
Louisville	5.00	22	34	1.93	1	12	4.58	22
Lynchburg*	7.59	18	26	2.62	1	25	4.12	16
Macon	8.36	16	20	6.25	1	55	4.52	15
Madison	5.20	10	20	2.24	1	13	3.84	25
Marquette	4.46	18	3	2.18	1	48	2.96	30

\*Broken record.  
†Partly estimated.

TABLE 2.—Maximum amounts and corresponding durations at 2.50 inches in 24 hours or more and at 1.00 inch per hour or more and maximum rate in inches per hour with duration—Continued

Station	Maximum amounts						Maximum rate in inch/hour	
	2.50 inches in 24 hrs.			1.00 in 1 hr.				
	Amount	Hours	Minutes	Amount	Hours	Minutes		
Memphis	9.30	18	16	5.68	4	0	5.78	
Meridian	9.57	34	22	4.14	2	32	5.90	
Milwaukee	5.76	11	23	2.94	1	27	4.00	
Minneapolis	5.34	15	28	2.37	1	12	10.20	
Mobile	11.59	19	17	4.75	2	42	5.40	
Modena				1.75	0	58	3.71	
Montgomery	10.25	44	37	5.18	2	43	8.01	
Moorhead	13.64	8	15	2.48	1	30	4.96	
Nantucket	4.57	23	55	2.23	0	52	2.57	
Nashville	5.19	24	22	3.24	1	32	4.85	
New Haven	9.05	33	42	2.61	1	26	6.78	
New Orleans	16.34	36	30	6.46	2	43	4.68	
New York	5.18	21	48	2.41	0	35	4.13	
Norfolk	6.64	17	16	2.28	0	48	3.72	
Northfield*	3.38	24	0	1.64	0	15	6.56	
North Head	3.69	24	0					
North Platte	3.82	2	15	2.57	1	3	3.78	
Oklahoma City	7.94	13	22	4.19	2	35	4.26	
Omaha	6.80	10	6	4.08	2	54	5.24	
Oswego	3.71	12	15	1.52	0	39	5.12	
Palestine	6.98	29	34	4.31	2	26	4.89	
Parkersburg	5.91	14	22	2.40	1	30	5.32	
Pensacola	17.07	23	52	14.45	9	35	4.85	
Peoria	5.52	8	32	3.09	1	33	4.00	
Philadelphia	7.14	40	27	2.66	1	13	4.44	
Phoenix	5.19	25	9	1.85	1	14	2.44	
Pittsburgh	3.22	23	30	1.76	1	15	4.05	
Pocatello	2.60	16	58	1.00	0	38	1.88	
Portland, Me.	6.61	37	5	1.48	0	23	3.86	
Portland, Oreg.	5.72	25	33	1.12	0	33	2.04	
Providence	6.17	18	51	3.17	1	38	2.82	
Pueblo	2.93	10	38	2.04	0	48	2.95	
Raleigh	9.04	36	5	4.17	2	0	6.69	
Rapid City	5.57	8	42	2.72	2	9	3.22	
Reno								
Richmond	7.26	13	46	6.98	2	35	4.36	
Rochester	3.13	8	9	1.98	0	30	3.96	
Roseburg	5.49	32	28	1.10	0	15	4.40	
Roswell	5.57	17	12	2.92	2	9	4.02	
Sacramento	3.35	20	44	2.33	1	33	1.50	
St. Louis	7.02	23	43	3.47	1	0	4.33	
Salt Lake City				1.05	0	30	2.10	
San Antonio	7.22	25	3	4.39	2	21	5.44	
San Diego	3.24	24	0	1.04	0	50	1.25	
Sandusky	5.95	9	42	3.76	1	6	3.45	
San Francisco	3.52	23	30	1.03	0	55	1.12	
San Jose								
San Juan	10.55	15	5	4.52	1	41	6.67	
Santa Fe	2.83	10	60	1.07	0	37	2.22	
Sault Ste. Marie	5.64	20	39	1.22	1	0	2.33	
Savannah	11.44	19	40	5.18	3	45	2.28	
Scranton	5.09	24	0	2.32	0	43	4.37	
Seattle	4.08	27	16					
Shelby	4.41	7	44	2.49	1	45	2.61	
Shreveport	18.03	39	4	4.04	1	43	6.68	
Sioux City	4.69	10	23	3.00	1	42	5.30	
Spokane								
Springfield, Ill.	5.94	6	52	2.64	1	33	4.20	
Springfield, Mo.	6.55	35	43	4.33	3	0	3.33	
Syracuse	4.79	7	55	4.52	2	13	4.27	
Tampa	7.81	14	55	4.33	1	12	5.06	
Tatooch Island	10.02	53	49	1.38	0	55	2.50	
Toledo	5.98	15	54	3.40	0	46	4.43	
Topeka	8.08	16	32	3.36	1	5	4.37	
Valentine	4.21	7	2	3.15	1	7	4.11	
Vicksburg	6.92	5	23	4.03	1	37	6.71	
Walla Walla								
Washington, D. C.	8.33	28	2					

TABLE 3.—Number of occurrences of rainfall of 2.50 inches in  
24 hours or over

**1** None.

\*Broken record.

TABLE 3.—Number of occurrences of rainfall of 2.50 inches in  
24 hours or over—Continued

STATION	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Oswego													5
Palestine	2	2	5	6	8	7	1	5	2	7	7	6	61
Parkersburg	1	1	2	2	2	3	4	2	2	2	6	11	13
Pensacola	7	6	8	14	6	10	17	18	17	6	11	127	23
Peoria			1	5	3	4	3	5	1	1	1	2	27
Philadelphia	1	3	3	2	1	4	7	3	1	2	2	2	2
Phoenix						2	3	1	1	1	1	1	2
Pittsburgh													7
Pocatello													1
Portland, Me.	3	3	6	3	2	2	3	3	2	4	1	1	32
Portland, Oreg.	3	3	1			3	3	3	1	6	1	2	12
Providence	1								4	1	1	2	18
Pueblo													2
Raleigh	1	1	2	5	2	3	9	10	9	2	2	2	48
Rapid City					4	2	2		2		1		11
Reno <sup>1</sup>													
Richmond	2	1	1	2		4	6	9	5	3	1	1	35
Rochester						1	1	2		1			5
Rosburg	1	1								1	3		6
Roswell													7
Sacramento	2	1	1	2		1							6
St. Louis	2		2	5	1	4	3	6	6	4	2	2	37
Salt Lake City <sup>1</sup>													
San Antonio	1	2	4	4	6	5	5	4	3	2			36
San Diego	1		1			4	3	2			1		4
Sandusky			1										3
San Francisco	2	2											7
San Jose	2	1	1								1		6
San Juan	6	2	2	9	11	3	5	4	7	2	10	5	68
Santa Fe													1
Sault Ste. Marie													5
Savannah	5	1		1		9	8	15	13	4	2	2	60
Scranton	1	1				1	6	3	2	3	1	2	18
Seattle													3
Sheridan													56
Shreveport	4	1	7	6	7	2	7	3	5	3	5	6	17
Sioux City				1	1	3	4	2	5		1		
Spokane <sup>1</sup>													
Springfield, Ill.													26
Springfield, Mo.	1		5	4	1	4	2	5	2	3	1	2	33
Syracuse	1				1		4	4	1	3	3		17
Tampa	2	6	5	3	8	10	12	13	11	5	2		77
Tatoush Island	12	10	1							3	9	11	59
Toledo			2	2	2	3				5	1		19
Topeka	1	2	2	4		4	3	4	8	2	4		34
Valentine						1		2	2	1	1		7
Vicksburg	8	11	14	12	11	3	4	4	3	5	7	9	91
Walla Walla													
Washington, D. C.	1		1	3	2	3	6	7	7	4	1		35
Wichita			1	1	5	8	3	5	5	2	6		38
Williston						1	3		1				5
Wilmington	4	1	1	4	3	3	11	10	15	7	5	2	66
Winnebemucca <sup>1</sup>						3	2	2	4	8	2		22
Wytheville			1										
Yellowstone Park <sup>1</sup>										1	1		
Yuma													2

<sup>1</sup> None.

TABLE 4.—Number of occurrences of rainfall of 1.00 inch in 1 hour or more

Station	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Abilene				10	23	10	6	12	8	5	3		77
Albany						2	5	3	3	1			13
Alpena				2	6	10	6	13	6	5			14
Amarillo				3	10	6	9	6	2	3			36
Asheville				6	13	11	12	8	7	3	3		76
Atlanta	2	2	5	4	6	13	11	12	8	7	3	1	34
Atlantic City						11	12	10	3	2			97
Augusta	2	3	2	8	20	26	20	8	7	1			
Baker <sup>1</sup>													
Baltimore				5	6	10	22	5	3				51
Binghamton				3	4	6	8	4	4				25
Birmingham	5	2	11	10	11	15	21	20	11	6	7	10	129
Bismarck				1	2	3	5	4	1				14
Block Island						8	7	2					23
Boise <sup>1</sup>													
Boston						1	6	4	1	1			13
Buffalo						1	5	2	2	2			10
Burlington						3	5	2	3	1			14
Cairo	2	2	4	8	12	17	9	3	3	4			61
Canton						2	5	2					9
Charles City			1	4	13	11	15	6					51
Charleston	1	1	2	4	14	13	34	29	16	8	2		124
Charlotte	1		1	5	17	16	24	9	4	1			78
Chattanooga	1		6	11	13	3	2	1					78
Cheyenne						6	17	12	4	2			8
Chicago				2	13	9	19	2	4	2			49
Cincinnati			1	4	3	16	6	5	2				37
Cleveland					4	7	5						16

TABLE 4.—Number of occurrences of rainfall of 1.00 inch in 1 hour or more—Continued

Station	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Columbia, Mo.	2	2	5	16	9	19	19	2	1	—	75	—	—
Columbia, S. C.	2	1	5	15	27	22	7	1	—	80	—	—	67
Columbus	—	—	1	4	6	10	3	—	—	—	24	—	7
Concordia	—	3	7	17	11	11	8	2	—	—	59	—	—
Corpus Christi	1	1	25	12	6	4	19	11	6	4	96	—	—
Davenport	—	3	1	11	13	11	10	3	—	—	52	—	—
Del Rio	1	3	4	12	11	8	4	6	7	4	60	—	—
Denver	—	—	1	6	3	—	—	—	—	—	11	—	—
Des Moines	—	—	10	11	7	8	9	2	1	—	48	—	—
Detroit	—	—	6	8	5	4	2	—	—	—	25	—	10
Devils Lake	—	—	3	5	5	4	—	—	—	—	17	—	—
Dodge City	—	2	4	9	9	8	3	—	—	—	35	—	—
Dubuque	1	4	9	9	9	13	8	2	—	—	48	—	—
Duluth	—	—	1	4	10	2	3	—	—	—	20	—	—
Eastport	—	—	—	3	1	3	3	—	—	—	10	—	—
Elkins	—	—	1	8	14	7	4	—	—	—	34	—	—
El Paso	—	—	—	4	1	—	—	—	—	—	5	—	—
Erie	—	—	6	8	8	3	—	—	—	—	25	—	—
Escanaba	—	—	1	4	3	7	—	—	—	—	15	—	—
Eureka <sup>1</sup>	—	—	—	—	—	—	—	—	—	—	—	—	—
Evansville	1	3	6	11	9	14	8	2	2	—	56	—	—
Fort Smith	1	4	6	10	6	10	13	5	4	—	59	—	—
Fort Worth	1	3	8	16	22	7	13	5	1	—	94	—	—
Fresno	—	—	1	—	—	—	—	—	—	—	2	—	—
Galveston	8	3	11	17	21	16	16	13	25	21	6	10	167
Grand Junction <sup>1</sup>	—	—	2	3	6	6	6	3	—	1	—	27	—
Grand Rapids	—	—	2	3	6	8	8	3	—	—	29	—	—
Green Bay	—	—	2	8	8	8	8	3	—	—	38	—	—
Harrisburg	—	—	2	5	8	11	6	5	—	1	—	27	—
Hartford	—	—	5	8	9	4	1	—	—	—	119	—	—
Hatteras	4	1	2	3	8	16	22	24	15	8	6	10	119
Hayre	—	—	—	1	—	—	—	—	—	—	2	—	—
Helena	—	—	—	—	—	—	—	—	—	—	1	—	—
Honolulu	4	5	7	2	4	1	—	1	4	9	3	10	50
Huron	—	—	3	10	9	3	—	1	—	—	26	—	—
Indianapolis	—	—	2	1	6	17	10	6	—	—	42	—	—
Jacksonville	1	2	3	5	15	31	39	26	20	8	2	2	154
Kalispell	—	—	—	—	—	—	—	—	—	—	1	—	—
Kansas City	—	—	1	1	10	17	9	12	13	4	1	—	68
Keokuk	—	—	4	17	11	12	10	1	1	—	56	—	—
Key West	5	3	6	19	27	8	17	23	28	3	4	—	144
Knoxville	—	—	1	9	16	13	6	—	—	—	45	—	—
La Crosse	—	—	1	3	10	12	15	5	1	—	47	—	—
Lander	—	—	—	1	1	—	—	—	—	—	2	—	—
Lincoln	—	—	1	4	9	11	13	11	1	—	50	—	—
Little Rock	1	4	12	11	11	12	18	9	5	3	88	—	—
Los Angeles	1	1	1	—	—	—	—	—	—	—	3	—	—
Louisville	1	2	2	2	7	13	9	6	—	1	—	43	—
Lynchburg*	—	—	1	3	7	15	5	1	2	—	34	—	—
Macon	2	3	8	5	16	23	20	8	5	2	1	—	98
Madison	—	—	4	5	11	10	10	1	—	—	41	—	—
Marquette	—	—	1	5	2	2	3	—	—	—	13	—	—
Memphis	2	4	6	6	7	8	7	9	4	5	3	61	—
Meridian	4	7	12	12	16	25	28	22	11	6	5	9	157
Milwaukee	—	—	1	4	6	6	7	4	2	—	30	—	—
Minneapolis	—	—	13	12	10	4	1	1	—	—	41	—	—
Mobile	8	8	21	27	22	25	47	34	13	18	16	12	251
Modena	—	—	—	—	—	4	1	—	—	—	5	—	—
Montgomery	7	9	16	17	13	16	20	17	16	3	8	5	147
Moorhead	—	—	1	8	10	8	1	—	—	—	28	—	—
Nantucket	—	—	—	2	3	6	3	4	1	—	19	—	—
Nashville	4	3	3	5	6	13	12	13	4	2	—	4	69
New Haven	—	—	—	6	10	10	4	—	1	—	31	—	—
New Orleans	9	8	19	29	29	29	45	36	26	22	9	5	266

TABLE 4.—Number of occurrences of rainfall of 1.00 inch in 1 hour or more—Continued

Station	January	February	March	April	May	June	July	August	September	October	November	December	Annual
New York	1	—	—	—	—	6	17	9	4	3	—	—	40
Norfolk	—	—	—	—	—	12	23	13	10	1	1	3	67
Northfield <sup>1</sup>	—	—	—	—	—	2	5	—	—	—	—	—	7
North Head	—	—	—	—	—	—	—	—	—	—	—	—	26
North Platte	—	—	—	—	—	6	7	6	1	1	—	—	71
Oklahoma City	1	5	16	13	11	9	7	5	4	—	—	—	43
Omaha	—	—	—	—	—	4	14	11	12	6	7	7	101
Oswego	—	—	—	—	—	1	4	2	3	—	—	—	38
Palestine	2	—	—	—	—	13	16	9	11	6	7	7	101
Parkersburg	6	6	12	27	15	12	38	38	20	19	12	11	216
Pensacola	—	—	—	—	—	1	2	9	12	13	1	1	64
Peoria	—	—	—	—	—	1	2	4	3	—	—	—	46
Philadelphia	1	2	5	6	13	11	8	—	—	—	—	—	6
Phoenix	—	—	—	—	—	—	3	1	2	—	—	—	32
Pittsburg	—	—	—	—	—	6	15	6	5	—	—	—	3
Pocatello	—	—	—	—	—	—	1	2	4	3	—	—	11
Portland, Maine	—	—	—	—	—	1	2	4	2	—	—	—	1
Portland, Oreg.	—	—	—	—	—	1	3	8	3	—	—	—	1
Providence	—	—	—	—	—	1	3	8	6	1	—	—	22
Pueblo	—	—	—	—	—	2	5	17	27	30	13	4	104
Raleigh	2	5	5	17	27	30	13	4	1	—	—	1	15
Rapid City	—	—	3	1	4	5	2	—	—	—	—	—	1
Reno <sup>1</sup>	—	—	—	—	—	2	4	13	19	17	7	2	64
Richmond	—	—	—	—	—	2	3	4	2	—	—	—	11
Roseburg	—	—	—	—	—	1	3	4	2	—	—	—	1
Roswell	—	—	—	—	—	4	3	4	2	4	2	1	20
Sacramento	—	—	—	—	—	1	2	1	1	—	—	—	1
St. Louis	1	5	3	6	13	14	1	2	—	—	—	—	55
Salt Lake City	—	—	—	—	—	1	2	1	1	—	—	—	1
San Antonio	1	4	14	19	14	6	7	8	8	1	1	1	83
San Diego	—	—	—	—	—	1	2	6	5	7	6	1	1
Sandusky	—	—	—	—	—	1	2	6	5	7	6	1	28
San Francisco	—	—	—	—	—	1	2	1	1	—	—	—	1
San Jose <sup>1</sup>	—	—	—	—	—	1	2	1	1	—	—	—	5
San Juan	7	4	4	12	18	18	11	6	20	15	22	8	145
Santa Fe	—	—	—	—	—	1	2	1	2	—	—	—	4
Sault Ste. Marie	—	—	—	—	—	3	3	2	2	—	—	—	8
Savannah	1	1	1	3	11	16	33	36	30	6	2	—	140
Scranton	—	—	—	—	—	11	13	9	3	—	—	—	37
Seattle <sup>1</sup>	—	—	—	—	—	—	—	—	—	—	—	—	—
Sheridan	—	—	—	—	—	1	2	1	1	—	—	—	25
Shreveport	2	1	8	11	16	9	8	7	10	1	1	1	108
Sioux City	—	—	—	—	—	3	13	11	7	10	—	—	44
Spokane <sup>1</sup>	—	—	—	—	—	1	7	10	6	1	—	—	52
Syracuse	—	—	—	—	—	1	7	10	8	9	1	1	25
Tampa	6	5	7	9	20	39	30	49	25	8	2	1	201
Tatooosh Island	—	—	—	—	—	1	5	4	9	7	1		